

***Polydora nuchalis* (Polychaeta: Spionidae), a New Hawaiian Record from Aquaculture Ponds¹**

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ABSTRACT: The spionid polychaete *Polydora nuchalis* was collected from the mud bottoms of penaeid shrimp and oyster culture ponds at two aquaculture farms on Oahu, Hawaii. The polychaetes formed masses of mud tubes, which contained egg capsules and early and late larval stages. *Polydora nuchalis* is not a shell-boring worm like the congener *P. websteri* that infects commercial shellfish, but is considered to be a pest because sediment and tube masses accumulate in the culture system. *Polydora nuchalis* was probably introduced to the Hawaiian Islands with shipments of shrimp from western Mexico to stock ponds at one of the aquaculture farms, but the means of dispersal to the other farm is presently unresolved. This accidental introduction of a commercially undesirable species occurred despite the permit system and quarantine regulations that are in effect.

EIGHT *Polydora* species are known from the Hawaiian Islands (Ward 1981a, Russo et al. 1988). Two of these, *Polydora armata* and *P. websteri*, are known to bore into carbonate materials; the former is found in coral rubble, and the latter forms mud blisters within the valves of oysters (Ward 1981a,b). An infestation of *P. websteri* in cultured oysters contributed to the collapse of a highly intensive aquaculture industry at Kahuku (Figure 1), Oahu (Bailey-Brock and Ringwood 1982, Bailey-Brock 1987). In that case the sources of the infection were thought to be from oysters brought into the culture system from Kaneohe Bay reefs (Figure 1) south of Kahuku and from spat and young oysters purchased from hatcheries on the east and west coasts of North America. Efforts to eradicate the dense population of *P. websteri* throughout the raceway and in the coral rock walls of the phytoplankton culture ponds were too late to effectively control the worm population, which continued to thrive.

There is considerable concern among aquaculturists to avoid such accidental introductions and to maintain cultured animals under

controlled conditions that do not favor potential pests and parasites. Nevertheless, the presence of mud tubes in culture ponds alerted researchers to a dense population of worms in an experimental oyster and penaeid shrimp project. This worm is *Polydora nuchalis* Woodwick, 1953, a polychaete previously unrecorded in the Hawaiian Islands.

MATERIALS AND METHODS

Study Sites

In June 1988, *P. nuchalis* was collected at Kahuku (Figure 1) from a polyculture trial in which the eastern oyster, *Crassostrea virginica*, was being grown in the effluent water from a commercial shrimp (*Penaeus vannamei*) pond. (This site is referred to as Kahuku A.) In January 1989, additional *P. nuchalis* were found in the bottom sediments of a drainage ditch (Kahuku ditch) adjacent to a separate, former shrimp research facility (Kahuku B) located closer to the ocean and ca. 1 km from the other shrimp pond where *P. nuchalis* was initially discovered. In previous years (1981–1987), this ditch had been used to carry effluent from the shrimp research facility and an adjacent oyster farm (Kahuku C) to a nearby settling pond—dispersion well system, approved

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FIGURE 1. Map showing the locations of the aquaculture facilities on Oahu.

for this use by the State of Hawaii Department of Agriculture. Both the research facility and the oyster farm discontinued operation some time ago and are now under new ownership. Neither oysters nor shrimp are presently being cultured at these sites.

During the period that the shrimp research facility was operational, shrimp that originated from north of Guaymas in the Gulf of California and other locations in Central America and Asia were introduced and held in quarantine in tanks at the shrimp research facility (Kahuku B). Effluent from the facility was discharged via the ditch into the settling pond–dispersion well system.

Oysters cultured at the oyster farm (Kahuku C) originated from Kaneohe Bay, Oahu, Hawaii or were imported from commercial hatcheries on the east and west coasts of North America. Both *Crassostrea gigas* and *C. virginica* were introduced onto this farm. Oysters cultured on this farm were grown in trays that were placed in trenches, and the effluent water from these trenches was discharged via the ditch into the settling pond–dispersion well system.

Methods

Worms from Kahuku A were collected from pond bottoms after the ponds were harvested and drained and from the sediment in the fiberglass tanks that held the oysters. Samples were taken in June, August, and late September

1988. Specimens were collected from the drainage ditch in January 1989 from compact mud and carbonate sediments that contained *Tilapia* nests and mangrove roots. Worms were removed from the tubes to confirm the specific identification and to find eggs and larvae that were retained in the tubes. Diagnostic features were examined with light and scanning electron microscopy (SEM), and a camera lucida was used to prepare illustrations of the setae.

RESULTS

Description

Polydora nuchalis was carefully described by Woodwick (1953) from California, so only a brief description of the Hawaiian material is given here to aid researchers in identifying this species. Specimens are deposited at the U.S. National Museum of Natural History (cat. no. 108604).

Worms measure 17–30 mm long and 1.0–1.8 mm wide across the anterior region. The prostomium is bifurcate (Figure 2a). There is a simple caruncle that extends to the anterior margin of the third setiger and a small median antenna resembling a blunt knob between the peristomium and the caruncle at the junction between the first and second setigers. The two pairs of eyes are situated at the bases of the palps (Figure 2a). The first setiger lacks notosetae but has a few short, winged neurosetae (Figure 2c). Setigers 2–4 have capillary setae in both fascicles (Figure 2d). Setiger 5 has a dorsal curved row of 8–10 heavy spines that are weakly curved, alternating with plumose companion setae and six short capillary notosetae (Figure 2a,b). The ventral fascicle of setiger 5 contains four to six short capillary setae (Figure 2e). The shape of the spines changes along the row; the most anterior are thick with a rounded tip (Figure 2f), middle spines have a more pointed tip (Figure 2g), and the most posterior spines have tapered tips (Figure 2h). There were two or three spines visible within the tissue. The companion setae also vary, although all are plumose; some are more finely tapered, with a longer plumose region than others (Figure 2i,j). Bifid, hooded,

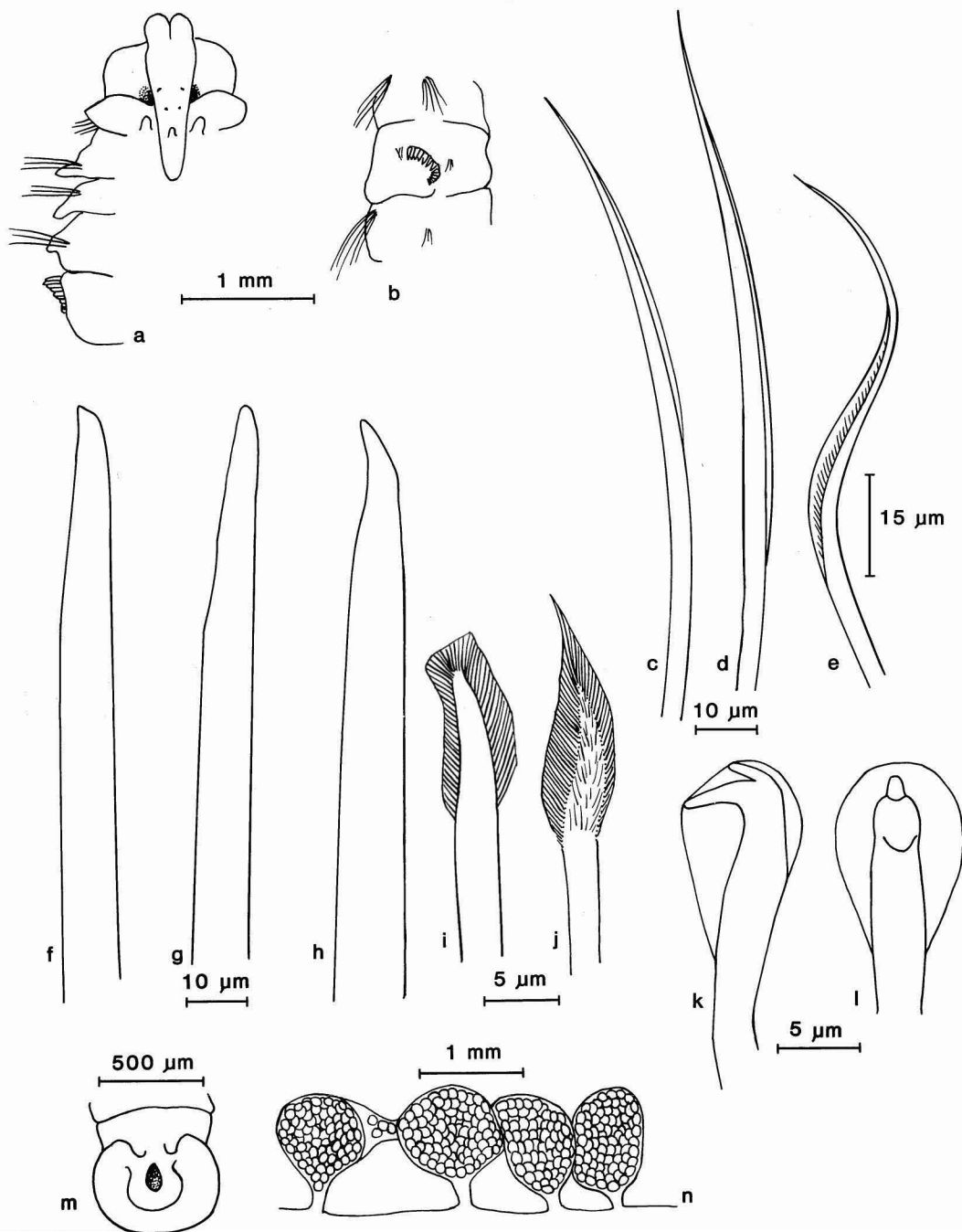


FIGURE 2. *Polydora nuchalis*: a, head and anterior region to setiger 5, dorsal view; b, right side of setiger 5; c, neuroseta of setiger 1; d, notoseta of setiger 5; e, neuroseta of setiger 5; f, most anterior spine of setiger 5; g, spine from middle of row of setiger 5; h, most posterior spine with tapered tip of setiger 5; i, anterior companion seta of setiger 5; j, most posterior companion seta of setiger 5; k, bidentate neuropodial hook from setiger 7; l, hooded hook, face view; m, pygidium with dorsal notch; n, chain of egg capsules.

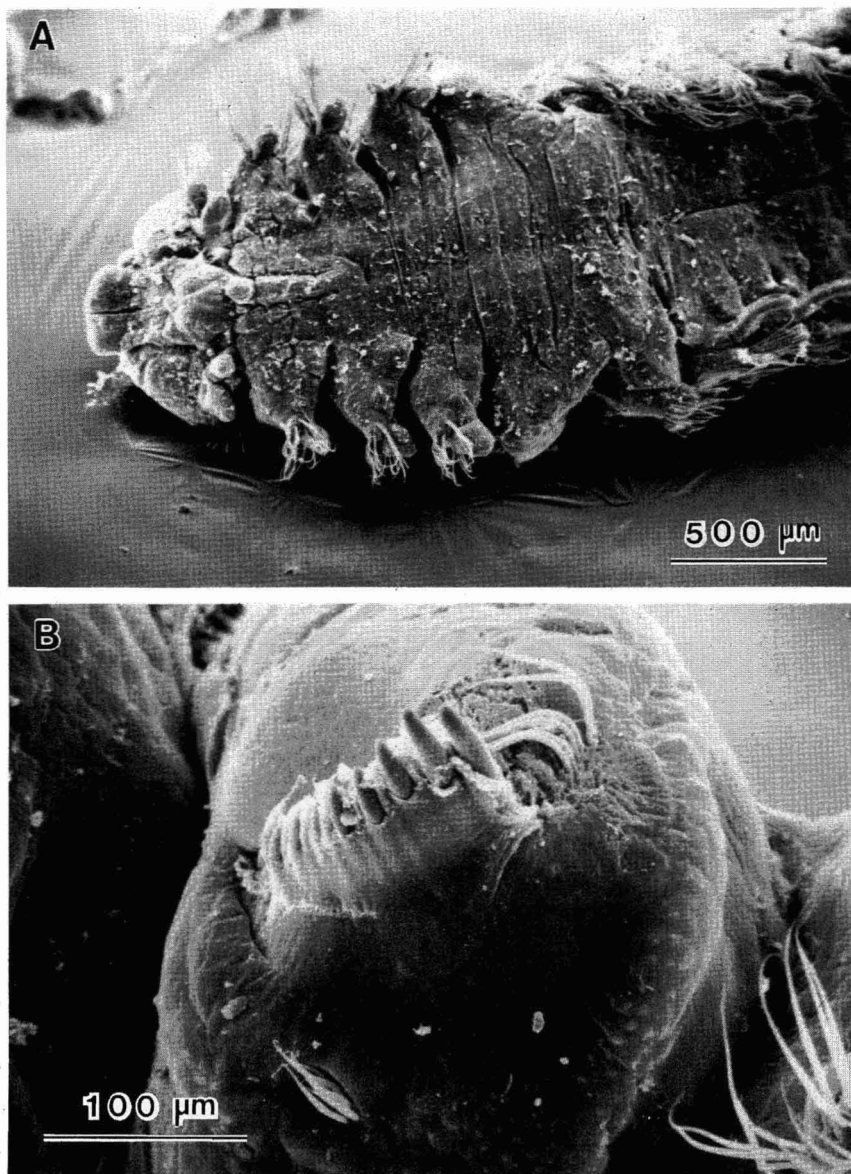


FIGURE 3. SEM micrographs of *Polydora nuchalis*. *A*, dorsal view of the anterior region with the palps removed. The bilobed prostomium, caruncle, a short occipital tentacle, modified fifth setiger, and branchiae are evident. *B*, fifth setiger showing the superior geniculate notosetae, curved row of stout spines and companion setae, and inferior capillary setae.

falcigerous neurosetae are present from setiger 7 (Figure 2*k,l*). Branchiae start on setiger 7 and continue to near the posterior end. They are long, meeting at the mid-dorsum anteriorly, but shorter on posterior segments. Poste-

rior setigers have capillary notosetae, and the neurosetae are bidentate hooded hooks. The pygidium is a flared cup with a dorsal notch (Figure 2*m*). Figure 3 shows SEM micrographs of *P. nuchalis*.

Polydora nuchalis is distinguished from *P. websteri* by having a small median antenna just posterior to the eyes and lacks the flanges on the spines of setiger 5 that are characteristic of *P. websteri*.

Life History of *Polydora nuchalis*

Strands of encapsulated egg masses (Figure 2n) and motile larvae were found when the tubes were opened, indicating that this species is reproductive at least during the summer months of June to late September and in January in Hawaii. Two kinds of larvae are produced: advanced larvae with 12 or more setigers that have a short dispersal phase before settling and tube building, and larvae with 3 setigers that have a much longer period of pelagic development and are more widely dispersed (Woodwick 1960). These two types of larval development permit rapid recruitment of juveniles or early release and a broader distribution before settlement and may be reasons for the success of this species in semien-closed bodies of water. *Polydora websteri* has a similar life history with short and longer term larvae and is also extremely successful in aquaculture facilities.

Distribution

The type locality of *P. nuchalis* is a sandy lagoon at Playa del Rey, Los Angeles, California, an area with alternate periods of rain and evaporation (Woodwick 1953). The associated polychaetes included *Capitella capitata* and *Streblospio benedicti*. *Polydora nuchalis* is also known from intertidal sandy substrates at the northern extremity of the Gulf of California, western Mexico, and near Bolinas, California (Blake 1980). In the Hawaiian Islands it has thus far only been found in the aquaculture ponds and the drainage ditch examined in Kahuku, Oahu (Figure 1). This local distribution and the history of the ponds suggest that the Hawaiian population was probably introduced with shrimp that originated from the northern Gulf of Mexico or with the oyster transfers made from hatcheries in California.

How *P. nuchalis* moved from the drainage canal (Kahuku ditch) to the pond on the adja-

cent shrimp farm site (Kahuku A) has not been explained. This drainage canal is physically isolated from the ocean and drains via a dispersion well. It is possible that the dispersion well communicates with the ocean, but dye studies done when the dispersion system was first established (late 1970s) did not show dye intrusion into the adjacent nearshore waters. The neighboring aquaculture farm ponds (Kahuku A) drain into a canal that eventually empties into a swampy area that communicates with the ocean. The dispersion well site and swampy area are separated by a distance of 1 km or more.

Personnel at both the shrimp farm and the research facility (Kahuku A and B, respectively) had undertaken measures to keep the facilities isolated from each other. The shrimp grown in the aquaculture ponds are fourth-generation Hawaiian-derived progeny (*Penaeus vannamei*), and, because the ponds are not on a dispersion well, only locally spawned, hatchery-reared shrimp were stocked for farm grow-out on the aquaculture farm. Shrimp stocked onto the farm had no known exposure to imported shrimp, water, or personnel at the former shrimp research facility. Both operations were purposefully isolated from each other for reasons of infectious disease control.

Associated Fauna at Oahu Aquaculture Facilities

Polydora nuchalis was found with *Capitella capitata* (Polychaeta: Capitellidae), another tube-brooding species that is tolerant of extreme environmental conditions, at both Kahuku A and the ditch sites. *Capitella capitata* occurred with *P. websteri* in the oyster raceways and phytoplankton ponds at the oyster farm (Kahuku C) that is no longer in operation. The capitellid is very hardy and survived in damp cracks and fissures in the floor of the ponds when they were drained and left to dry out.

Abundant nematodes and the arborescent bryozoan *Hyacinella vaihiraiae* were found among the tubes of *P. nuchalis* at the operational farm (Kahuku A). A third spionid, an unidentified species of *Pseudopolydora*, was

collected from oyster mariculture tanks at Mariculture Research and Training Center of the University of Hawaii, Kualoa (Figure 1), Oahu (Ward 1981a,b). This species can be distinguished from the two *Polydora* species by the absence of the occipital tentacle and the presence of two curved rows of setae on setiger 5, an outer row of lanceolate and an inner row of falcate setae. *Pseudopolydora* sp. has not been found at the Kahuku sites.

DISCUSSION

The realization that *P. nuchalis* is probably an accidental introduction to the Hawaiian Islands and that the species could possibly become established in reef habitats is cause for concern. Even though *P. nuchalis* does not affect the marketability of cultured species, it does affect the pond environment by accumulating sediment and tubes on the pond bottom and may occlude drains and plumbed pipes. In contained systems these spionids may compete with the filter feeders (e.g., commercial bivalves) for planktonic food and cover surfaces that were previously substrates for microbial and algal growth. These microorganisms are thought to be an important natural food source for commercially raised shrimp that are fed a pelletized feed (K. Leber and J. Wyban, pers. comm.). The worms and their larvae may be eaten by shrimp or fish, although the tubes may be a deterrent to predators. At this time a detrimental effect caused by *P. nuchalis* to shrimp cultured on the farm has not been recognized. However, the spionid is considered a pest in the experimental oyster culture trial (C. Y. Lam, pers. comm.).

The known distribution of *P. nuchalis* now extends from California to western Mexico and the Hawaiian Islands. This spionid may have been introduced to other localities with aquatic animals purchased by aquaculture companies. Dispersal to new locations by modern transportation methods (e.g., fast-moving ocean vessels [Carlton 1987] and, in this case, aircraft) can rapidly change the distributional range of a species or group of species. Viable dispersal will occur when conditions are suitable for the introduced species at a new loca-

tion. The Hawaiian Islands are a major receiver area for species introduced from western and eastern Pacific boundaries via major shipping routes (Carlton 1987). Hawaii now has a large number of introduced species of marine invertebrates and algae in addition to its natural complement of indigenous and endemic species, especially reef fishes (Randall 1985), amphipods, and molluscs (Kay and Palumbi 1987).

The accidental introduction of species associated with cultivated animals is a problem to aquaculturists because many of these hitchhikers are pests or predators that can rapidly become established and reach epidemic proportions in intensive mariculture (Bailey-Brock and Ringwood 1982, Willan 1987). Hawaiian quarantine and importation procedures regulate the entry of alien species, but some may escape notice because they are inconspicuous (e.g., as swimming larvae, or as tube dwellers or borers within the shells of imported bivalves). Permits, an advisory board review of every species requested for importation, and examination of each shipment at the airport have been part of the importation procedure since the early 1970s. Before this there were numerous attempts to introduce species to fill voids in the natural community (e.g., several fishes [Brock 1960, Randall 1987]) and for economic ventures (e.g., clams and oysters [Brock 1960]). Some of the successful introductions, whether well-intentioned additions to the native fauna or passive immigrants, had a negative impact on the marine community by displacing indigenous species and desirable coral reef fishes (Randall 1987).

The polychaete *P. nuchalis* is apparently a recent accidental introduction to Hawaii that is currently very successful in the brackish culture systems at Kahuku, Oahu. It may still be contained in the ponds, or it may already have become established in nearshore waters. Its presence at two sites could represent an initial introduction to the second site and dispersal to the first site. A less likely possibility is that two separate introductions to Hawaii have occurred with culture animals at the two farms. The introduction of *P. nuchalis* is an example of what can happen despite thorough quarantine and permit procedures.

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